LIFE HISTORY OF THE WEEVIL *EUHRYCHIOPSIS LECONTEI*, A POTENTIAL BIOLOGICAL CONTROL AGENT OF EURASIAN WATERMILFOIL[1]

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ABSTRACT: We followed weevil life history in the lab and phenology in the field. In lab cultures, weevils progressed from eggs to adults in approximately 30 days. Females laid an average of 1.9 eggs per day; hatching success was 87%. In a Vermont lake, weevil adults and eggs were first found in late May. Thereafter there was a cyclic series of peaks in weevil stage abundance; there appeared to be three generations of weevils each summer in Vermont. This weevil is being evaluated as a possible agent of biological control.

Euhrychiopsis lecontei (Dietz) (Colonnelli 1986), a North American aquatic weevil, has potential as an agent of biological control for Eurasian watermilfoil [*Myriophyllum spicatum* (L.)]. Eurasian watermilfoil is a nuisance weed found throughout North America (Couch and Nelson 1986). In laboratory and field trials the weevil had a significant negative effect on Eurasian watermilfoil (Creed and Sheldon 1993), but not on native plants (Sheldon and Creed 1995). In the field in two lakes without weevils, when enclosed with weevils Eurasian watermilfoil did not increase in biomass over the growing season and by the end collapsed, contrary to control plants in enclosures without weevils (Sheldon and Creed 1995). In another lake, weevils were associated with an extensive decline of Eurasian watermilfoil (Creed and Sheldon 1995).

This native weevil is feeding on an exotic plant. Prior to the introduction of Eurasian watermilfoil the weevil most likely fed on native *Myriophyllums*. In Alberta, Canada where Eurasian watermilfoil has not been found, *E. lecontei* was found on northern watermilfoil, *Myriophyllum sibiricum* Komarov (= *exalbescens* Fernald) (Creed and Sheldon 1994).

The life history and phenology of this potentially important weevil has not previously been documented.

METHODS

To follow the life history *E. lecontei* we set up growth chambers in a controlled lab setting. We collected < 30 cm long Eurasian watermilfoil stems

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from local Vermont lakes and planted them into cups of autoclaved lake sediment then enclosed each in a clear, cylindrical polycarbonate chamber (30 cm long, 6 cm inside diameter). Each chamber was capped with a lid of 202 μm Nitex mesh. The chambers were set in aquaria filled with aerated tap water. Each chamber was also individually aerated. Chambers were housed in a light room, illuminated by artificial light under a 16 h light : 8 h dark regime. Water temperatures ranged from 21.5 - 24.0 °C.

Adult *E. lecontei* were collected from *M. spicatum* and placed in the chambers. Within 24 hours after an egg was laid on an Eurasian watermilfoil plant, we transferred the plant and egg into a new chamber, and examined the egg daily until hatching. Each newly hatched larva was transferred to the meristem of an undamaged Eurasian watermilfoil plant in a chamber. Plants were added to the chambers, usually every second or third day, when the plants in the chambers had extensive apical damage. Late instar larvae formed pupal chambers inside plant stems. Plants were handled often, and many stems containing pupae broke.

Because the repeated handling could have affected pupal duration in the lab, we also looked at pupal duration in the field. We put late instar larvae on *M. spicatum* stems rooted in sediment in a local lake. The larvae and a portion of the plant stem were enclosed in a polycarbonate cylinder (30 cm by 4 cm diameter). The ends of the chambers were capped with foam to prevent weevil escape and allow air exchange. The dates of initiation of pupal phase and adult emergence were recorded.

In the lab, each newly emerged adult was removed from its chamber. Weevil sex could be determined by the shape of the pygidium: flat (female) or knobbed (male) (C. O'Brien, Florida A. and M. University, Tallahassee Florida, personal communication). For quantification of the lifetime egg production by a female, we placed each newly emerged female in a chamber with two males and from three to six *M. spicatum* stems with intact meristems. Plants were replaced when there was extensive feeding damage or there were many (>5) eggs per meristem. Dead males were replaced. The number of eggs each female laid was recorded every 3-4 days until she died.

To see whether weevils could survive on a different genetic stock of Eurasian watermilfoil we set up a batch culture in the lab. Weevils were placed in an aquarium containing *M. spicatum* collected from Lake Minnetonka, Minnesota, USA. The Eurasian watermilfoil in Lake Minnetonka is gentically different from Vermont Eurasian watermilfoil (G. R. Furnier, University of Minnesota, St. Paul MN, personal communication).

To determine if weevils could live on native watermilfoil, weevils were collected from *M. spicatum*, and placed in an aquarium with the native northern watermilfoil, *Myriophyllum sibiricum*. We followed both of these cultures qualitatively, noting adult survival, deposition of eggs on plants, and evidence of tunneling damage by weevil larvae.

E. lecontei phenology was followed in Lake Bomoseen, VT during the summers of 1991-1994. At three sites, transect lines were set up running perpendicular to the shore. On each transect, the upper 40 cm of 10 plants were collected. Plants were taken at regular intervals over the transect line, and three lines were run at each site; n = 90 stems per date. Plants were examined under a dissecting microscope; all weevils were removed and counted. In 1991 collection started in early July. In 1992, and subsequent years, samples were started in April, with weevils first being collected in mid-May. *M. spicatum* apical shoots were collected weekly from in 1991 and 1992, and every third week in 1993 and 1994.

RESULTS AND DISCUSSION

In the laboratory, eggs were laid on apical meristems. Eggs were elliptical, approximately 0.52 (± 0.06, mean ± SE) mm long and 0.39 (± 0.05) mm wide (n = 36). First instar larvae fed on meristematic tissue for 3-5 days. Later instar larvae spent most of their time inside the stem, resulting in a hollowed-out stem. Sometimes, particularly when larvae reached the end of an internode, larvae burrowed out, spiraled across the outside of a stem to a new internode, then burrowed back into the stem. Larvae were usually found in the top third of the plant. Late instar larvae were up to 4.5 mm long. Puparia were formed inside the stem and tended to be found further down in thicker (> 4 mm) portions of the stem. Adults were small, typically between 2 and 3 mm (2.85 ± 0.88 mm, n = 35) from the anterior edge of the eye to posterior end of the pygidium, and were usually found on the top third of the plants, where they fed on both leaves and stem tissue. In the lab, all of the life history stages took place entirely under water.

Under these laboratory conditions with temperature ranging from 21.5 to 24°C), the duration of the egg phase was 3.9 (± 0.2, n = 48) days. Larval duration averaged 13.0 (± 1.8, n = 9) days. Pupal duration in the lab averaged 13.0 (± 1.5, n = 5) days. The sum of these values suggests that the average time between egg deposition and emergence as an adult is approximately 30 days. Mean pupal duration on rooted plants in the field was 9.6 (± 1.2, n = 24) days, reducing the estimate from egg to egg as 26 days.

Because it was difficult to get weevils through the pupal phase, we had only 7 unmated females for which we knew the date of emergence. Total egg production for these females ranged from 3 to 562 eggs per female with a mean of 1.9 (± 0.4) eggs laid per female per day. Eggs were preferentially laid on the apical meristem. If eggs were already present on the apical meristem, eggs were often laid on the uppermost lateral meristems or on leaves near the plant apex. Hatching rate of eggs was 87.3%. Normally a few eggs were laid on each meristem in a chamber, however in a concurrent experiment under similar conditions, when weevils were enclosed with few plants, we found as

many as 29 eggs on a single plant. In the lab, female length of life as an adult ranged from 11 to 162 days.

For the batch culture of weevils with *M. spicatum* from Minnesota, larvae and adult weevils from Vermont fed on the Minnesota plants, and eggs were laid and hatched. In the batch cultures of the native watermilfoil *M. sibiricum*, adults fed on the plants and eggs were laid. Qualitatively, there were fewer adults generated from the native watermilfoil batch cultures than from Eurasian watermilfoil from Minnesota.

The life history data collected in the laboratory are consistent with our observations of *E. lecontei* phenology in the field (1991-1994); time from egg to egg was about 26 days, which could yield three generations of weevils each summer. In Lake Bomoseen there appear to be three generations of weevils each summer. The abundance of each life stage was cyclic (Figure 1). In the spring the first weevils collected were adults, then eggs. Peaks in egg abundance were followed by increased larval densities, followed by peaks in the abundance of pupae and adults. Thus, although the sample sizes were low in some cases for quantifying length of life history stage, the prediction for duration from egg to egg from lab data was 26 days, similar to what we found in Lake Bomoseen.

In September, densities of weevil eggs declined, followed by a decline of larvae, then pupae, then adults. Thereafter no weevils were found in the lake. Adults appear to overwinter terrestrially in leaf litter along lake margins (C. O'Brien, Florida A. and M. University, Tallahassee Florida, personal communication). Adults have been collected in sweeps of shoreline vegetation in the fall (David Ragsdale, University of Minnesota, St. Paul MN, personal communication). We found one adult weevil in terrestrial soil samples collected in October, five meters inland from the edge of Lake Bomoseen.

The patterns of egg laying and adult and larvae location in the field, were also consistent with the lab studies. Weevil eggs were found primarily on the apical or other meristems nearest to the water surface. If there were few meristems available, eggs were found on any meristem, or apical leaves. Larvae were usually found in the top meter of the plant. Pupae were typically found further down the stem (>0.5 m) where the stem is thicker (> 4 mm). Adults were usually found on the top one meter of plant.

The current range of the weevil in North America is not well known. *E. lecontei* previously had been found in Iowa, Michigan, Wisconsin, Alberta, British Columbia, and Saskatchewan (O'Brien and Wibmer 1982). We have found weevils in Connecticut, Massachusetts, New York, and Vermont. *E. lecontei* have also been found in Minnesota (Newman and Maher 1995) and they have recently been collected in Illinois (M. Pfister, Lake County Health Department, Chicago, IL, personal communication). Creed found weevils on northern watermilfoil, *M. sibiricum*, in western Washington (Creed and Sheldon 1994).

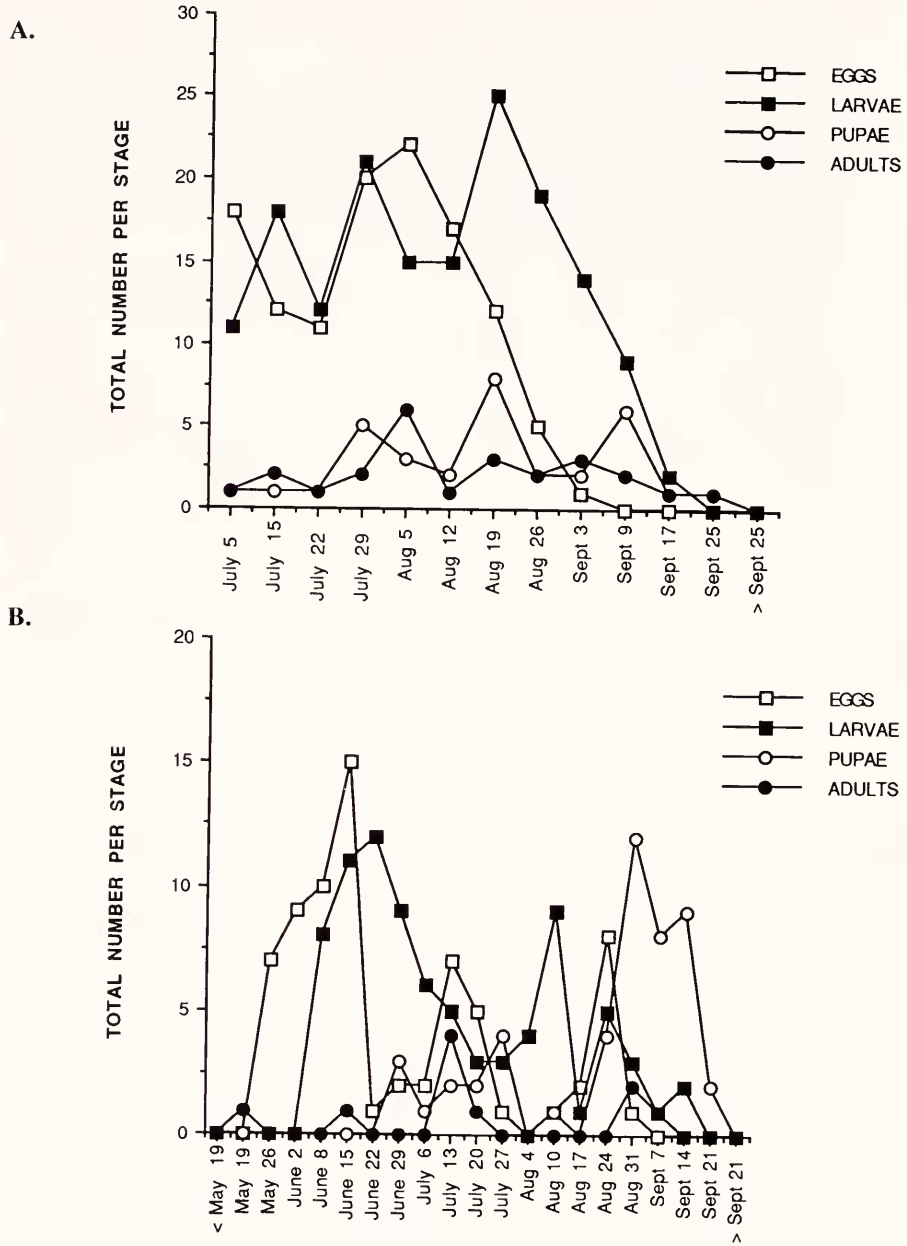

Figure 1. Phenology of weevil life history stages in a Vermont lake. Data are from A. 1991 and B. 1992. Patterns of frequency of life history stages were similar in 1993 and 1994.

E. lecontei may be a suitable agent for the biological control of Eurasian watermilfoil. Weevils have a significant negative effect on *M. spicatum*. At the same time, weevils did not have a significant impact on native plant species (Sheldon and Creed 1995). Other insects found in North America have been evaluated as potential biological controls for Eurasian watermilfoil including a moth [*Acentria ephemerella* (Dennis & Schiffermüller; Painter and McCabe 1988)], another weevil (*Phytobius leucogaster* Marsham; Buckingham and Bennett 1981), and a midge (*Cricotopus myriophylli* (Oliver; Kangasniemi and Oliver 1983, MacRae *et al.* 1990, Kangasniemi *et al.* 1993). *E. lecontei* may be a more effective biological control agent because they have a relatively long lived feeding adult phase, unlike *A. ephemerella* (Buckingham and Ross 1981) and *C. myriophylli* Kangasniemi *et al.* 1993) facilitating culturing; they are specific to *Myriophyllum*s unlike *A. ephemerella* (Buckingham and Ross 1981), their phenology is well timed, unlike *C. myriophylli* (Kangasniemi *et al.* 1993); and *E. lecontei* causes significant damage to the apical submersed portion of the plants, unlike *P. leucogaster* which feed primarily on flowers (Buckingham and Bennett 1981).

If *E. lecontei* is used as a biological control agent, it should be noted that all life history stages remain in the apical portion of the plants. Aquatic weed harvesting, a common control technique for Eurasian watermilfoil, removes the top 1-2 m of the plants.

While use of a native insect for biological control of an exotic plant is unusual, it may prove efficient and pose fewer potential drawbacks than introducing an exotic biological control agent. *M. spicatum* has a similar life history and phenology as native watermilfoils. Presumably this native weevil is coevolved with the native watermilfoils, which decreases the probability of damage to non-target plant species. The weevil coexists with *M. sibiricum* in both the United States and Canada.

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